Chapter 9

Principles of Exercise and Its Role in the Management of Diabetes Mellitus

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Additional information is available at the end of the chapter

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1. Introduction

It is known that a sedentary life style diminishes life expectancy and worsens existing chronic illnesses. Exercise not only promotes health but also prevents illness and can be used in the treatment of most of the well-known metabolic and chronic diseases. It reduces insulin resistance, helps regulate blood glucose, lowers uric acid and triglycerides and leads to an increase in the HDL/LDL cholesterol ratio [Banfi et al., 2012].

For a healthy beginner the intensity of the exercise should be at a specific percentage of their age-predicted maximum heart rate (calculated as 220 - age). A practical method to determine the appropriate exercise intensity is to use the "talk test" [Quinn, 2011]. This refers to an intensity of exercise that allows individuals to still talk to a partner exercising with them without any dyspnea. Individuals should slow down if they cannot speak to their partner comfortably.

Exercise is recommended for all patients with diabetes mellitus (DM) if there is no contraindication. However, it is important that they are educated regarding the impact of exercise on their blood glucose levels. Insulin dose adjustments are required when individuals with DM exercise to ensure that their plasma glucose levels are regulated. Exercise facilitates injected insulin absorption via increased blood flow to muscles and this may result in hypoglycemia. Therefore, the site of the insulin injection should not be the extremities or muscles contracting during exercise. The insulin response to exercise and hypoglycemia risk differs from one patient to the other and therefore individual evaluation and education is mandatory. Duration and intensity of exercise, injection placement, previous insulin dose and timing determines patients' insulin requirements when they exercise.

Patients with diabetes mellitus are advised to carry an identity card or a bracelet indicating that they are diabetic, especially when they are exercising alone.

2. Healthy life

A healthy life can be maintained by following all the recommendations that help protect against the development of metabolic and non-communicable diseases (NCD) (chronic diseases). There are a number of studies advising exercise and dietary interventions to maintain wellness [ADA, 2008 & Scott, 2005]. It is known that a sedentary life style worsens cardiopulmonary capacity and existing chronic illnesses and diminishes life expectancy. A number of studies have investigated the optimal exercise model for preventing or reducing NCDs, including the type, duration, intensity and mode of exercise [Jeon et al., 2006 & Kruger et al., 2009]. It is important that exercise programming is individualized.

3. Definitions of physical activity exercise and sports

Examples of physical activity are occupational activities and walking slowly (lower than 80 steps per minute) for short periods [Ogilvie et al., 2007]. Although physical activity refers to body movements that require active muscle contraction and energy expenditure, the effects of regular daily activity on metabolism and physiological capacity are different and less than those of exercise.

Exercise is defined as body movements that are planned and organized. These are whole body or selected muscle group movements that are performed regularly with the aim of achieving a specific level of fitness. When investigating the effects of exercise on an individual it is important to consider their physiological capacity, eating habits and life style. Regular exercise helps regulate blood glucose levels independently from its weight-loss effect [Boule et al., 2001]. The exercise-induced increase in lean muscle mass may be responsible for the reduced weight-loss. The duration of exercise is regulated based on the intensity of exercise and how it impacts on thermoregulation, cardiopulmonary capacity and fatigue. A short exercise period can be performed as part of a warm up to enhance sports performance.

Currently, the words exercise and sports are incorrectly used interchangeably. Exercise refers to planned and provoked body movements that can be modified according to personal daily conditions and medical aims. Sport refers to a specific sport ritual with its accompanying rules and mandatory time and may be performed at a recreational or competitive level. Swimming is an exercise however it is also a sport and may be performed competitively according to time or distance. The energy expenditure and intensity of movement is not regulated for individual wellness during sports, unlike exercise where there is usually a “prescription”. Sports may become a cultural subject and have intellectual benefits in addition to positive effects on physical and moral capacities.

In medicine, exercise is considered to be all the activities that are measurable; where gains and losses can be calculated; and where intensity, duration and mode can be planned according to needs of the person.

4. Physiological and metabolic effects of exercise

It is well known that exercise affects both physiological and metabolic mechanisms of humans. Through these mechanisms, exercise not only promotes health but can be used as "medicine" to prevent and treat various diseases including NCDs.

4.1. Cardiac and pulmonary diseases

In relation to cardiac and pulmonary diseases; exercise results in physiological myocardial hypertrophy that is accompanied by an increase in stroke volume, slower heart rate and improved collateral circulation [Burton et al., 2004]. It also promotes an increase in respiratory capacity that is accompanied by increased O_2 transport, a considerable decrease in peripheral vascular resistance and diastolic blood pressure, increased fibrinolytic activity, and increased sarcolemma and myoglobin in muscles. In addition, exercise may strengthen the rectus abdominus muscle that helps to increase endurance capacity and protect against postural hypotension. Patients suffering from respiratory distress have demonstrated a considerable recovery with the help of respiratory muscle exercises [Cinar et al., 2011].

4.2. Endocrinology and metabolism

Most diseases, especially malignancies, have catabolic effects on the body. Exercise has an anabolic effect and the positive effect of exercise on appetite has been suggested as an explanation for its anabolic effect. However, exercise does not always result in an increased appetite. Exercise has been shown to normalize the appetite as well as reduce the excess drive for feeding. Therefore, exercise has regulator effect on abnormal appetites [Hopkins et al., 2010]. Exercise reduces insulin resistance, helps regulate blood glucose, lowers uric acid and triglycerides and leads to an increase in the HDL/LDL cholesterol ratio, glycogen stores, cortisol and growth hormone secretion [Banfi et al., 2012]. Although exercise facilitates glycolysis and increases the transport of glucose into the muscle cell, hypoglycemia is rarely seen in non-diabetics. Blood glucose level is regulated hormonally during prolonged exercise or when blood glucose levels are low. Specifically, glucagon and catecholamines increase while insulin secretion diminishes and the liver continues to release glucose.

4.3. Obesity and weight control

Health professionals recommend a combination of exercise, diet and lifestyle changes for weight-loss. Weight loss obtained solely from exercise is negligible. Energy expenditure during a single, acute, 60 minute bout of exercise does not result in significant weight-loss. For example, a person with a mass of 70 kg and a height of 170 cm, walking at 80 steps per minute, will expend approximately 100 kcal in an hour, the amount of kcals found in three average sized apples or 25 grams of carbohydrate or 11 grams of butter. A reduction in body-weight after exercise typically reflects water loss because of sweating and urination. A fat loss of 700 kcal (1 gram fat equal to 9kcal) due to aerobic exercise is preferable to a 700 kcal food restriction, although this kind of heavy exercise is not suitable for most individuals. Therefore, in most situations, the exercise, dietary and lifestyle habits of

individuals need to be planned to optimize weight and weight-loss. It is important that weight-loss reflecting a reduction in fat mass should be monitored over time, for example monthly, rather than over a few hours or days.

4.4. Metabolic syndrome

Increased and inappropriate eating behavior and a lack of physical activity is associated with the metabolic syndrome. Insulin resistance, obesity, hypertension, dyslipidemia and stroke are associated with this syndrome. Exercise has been shown to protect individuals from developing metabolic syndrome that could be result in DM [Onat, 2011].

4.5. Musculoskeletal diseases

Exercise is important for musculoskeletal strength maintenance and the prevention of postural abnormalities. Growing children should be advised to exercise. The majority of the postural abnormalities in adulthood are related to muscular weakness.

4.6. Osteoporosis

Sedentary behavior is one of the leading causes of osteoporosis. Physicians recommend exercise, dietary and supplement alterations as well as sunlight exposure to prevent and treat osteoporosis. Exercise has been shown to increase or maintain bone density [Iwamoto, 2011].

4.7. Mental health

Exercise reduces depression, increases optimism and regulates biorhythms. Research has suggested that group exercise and physical activity have benefits on psychological wellness [Tordeurs et al., 2011].

5. Medical evaluation as a part of exercise planning

Cardiac output increases in parallel to exercise intensity. During exercise, there is a redistribution of the cardiac output, with an increased blood flow to the contracting, exercising muscles and a reduction in flow to other organs, for example the gastrointestinal system. Performing exercise while experiencing increased blood flow to the gastrointestinal system due to a heavy meal, results in a circulatory burden. The energy expenditure of food digestion depends on the nature of the meal. The process of protein and carbohydrate digestion increases energy expenditure. Therefore, eating, particular protein and fried food, just before exercise should be avoided. Dietary consultation is recommended prior to participation in exercise of different modalities and intensities.

Exercise is influenced negatively by the following factors; an acute increased circulatory burden when performing resistance exercise, unsuitable durations and intensity of endurance exercise, inappropriate clothing and shoes, poor environmental conditions, inadequate healing of existing injuries, inadequate warm-up, heavy meals before exercise, and fatigue (Table 1).

1.	Acute circulatory burden
2.	Unsuitable exercise planning
3.	Inappropriate wearing
4.	Environmental conditions
5.	Inadequate warm-up
6.	Heavy meals before exercise
7.	Fatigue

Table 1. Factors negatively affecting exercise

The present and past health status of individuals, together with their exercise history, should be determined before they participate in exercise. Individuals with a history of hypertension, DM and coronary artery disease should undergo a more in-depth examination. American College of Cardiology (ACC) and American Heart Association (AHA) guidelines recommends that men ≥40 years and women ≥50 years who would like to perform heavy exercise must undergo an exercise stress test that is supervised by a physician [ACC/AHA, 1997]. Individuals who did not participate in exercise until the age of 20 years should be advised not to perform heavy exercise, but rather light aerobic exercise, at the start of an exercise program. In such individuals, there will be an improvement in physical capacity, including metabolic adaptations, although the degree of cardiovascular adaptations is unclear. In more experienced individuals, such as marathon runners, they may have hypertrophied myocardial muscles with the diameter of their coronary arteries being larger than that of normal. However, these changes may be because of heavy training. Exercise performed at a mild to moderate intensity may result in these beneficial, physiological adaptations.

For individuals at risk, ECG and blood pressure evaluations should be performed by a physician before the individual participates in an exercise program. A treadmill stress test is recommended for these individuals. Pre-participation medical evaluations are required for pregnant women, women with history of gestational diabetes mellitus (GDM), diagnosis of DM before the age of 40 years, myocardial infarction (MI) and stroke, hypertension, dyslipidemia, smoking, and family history of premature death. Persons who experience palpitations, tachycardia, sweating and dyspnea at the beginning of exercise may be at risk need to be examined.

The American Heart Association (AHA) and the American College of Sports Medicine (ACSM) has a pre-participation screening questionnaire that should be used to determine whether individuals can start exercising or should have a medical examination prior to starting an exercise program. It is called the **AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire** (http://www.wm.edu./offices/recsports/documents/fitnessquestionnaire.pdf).

5.1. Recommendations for medical evaluations

If there are no contraindications, for example arterial insufficiency, then exercise should be encouraged as long as a diabetic is educated regarding the effects of exercise on blood

glucose levels and how to regulate their glucose levels when exercising. Patients that have severe arterial problems like angina pectoris, claudication or proliferative retinopathy should not perform heavy exercise. Exercise-induced pain, early fatigue, difficulty in breathing, tachycardia, excessive sweating, patients prone to hypoglycemia, prolonged tiredness after exercise are all signs that require evaluation and a decision should be made as to whether the individual should continue exercising. In these cases, physicians should check if there is a severe underlying medical illness (Table 2).

1.	Angina pectoris
2.	Retinopathy
3.	Hypoglycemia attacks
4.	Respiratory problems
5.	Early fatigue
6.	Tachycardia

Table 2. Whom to evaluate?

Individuals should be encouraged to start an exercise program and improve their wellness as this will enhance their quality of life. Physicians should ensure that they have an understanding of the effect of exercise that they "prescribe" for medically ill patients. Consideration of the disease and medical history will reduce the risk of harm, and enhance the benefits of the exercise.

5.2. Contraindications for exercise

Patients using insulin and who are at risk for hypoglycemia should avoid solitary sports like mountain climbing or diving. In addition, if the hypoglycemia is uncontrolled, this is also a contraindication for exercise. High intensity exercise is not recommended for individuals with proliferative retinopathy as the risk of hemorrhage increases [Sigal et al., 2006]. For patients with a history of coronary artery disease or if there is suspicion of coronary artery disease, a consultation with a specialist is required prior to starting an exercise program. To estimate coronary artery disease risk, calculation instruments are present and there is one available on the American Diabetes Association web site: (American Diabetes Association's Diabetes PHD (Personal Health Decisions) (http://diabetes.org/diabetesPHD).

Individuals suffering from severe peripheral neuropathy should be advised about their risk of injury during exercise. For example, they may have balance problems or difficulty in walking that places them at risk for falling. Patients that experience postural hypotension, induced by autonomic neuropathy or dehydration (related to severe sweating) must be evaluated medically prior to exercise participation. Although high intensity exercise does not cause microalbuminuria, it is not usually recommended as it may cause slight but transient proteinuria. There is currently no consensus regarding whether exercise-induced proteinuria causes renal impairment. Albumin is typically not found in urine after exercise unless there is a glomerular damage.

6. Exercise prescription

Before beginning an exercise program, balance, flexibility, joint pathology, muscle strength and stability should be examined, with precautions taken to prevent the occurrence of injuries. If possible, it is recommended that light strengthening exercises should be performed prior to the start of the exercise program. Without examining the above parameters it is possible that individuals will not cope with a structured exercise program and may become de-motivated and drop-out.

For the elderly and other individuals who struggle with ambulation, non-weight bearing exercises are recommended initially, for example riding a bicycle, swimming or light exercise in the water. These activities will enhance their exercise capacity. For other individuals, weight-bearing exercises such as walking, jogging, or rhythmic group dancing are recommended.

Walking is the preferred exercise modality as it is cheap and easy to perform. When starting an exercise program, this may be the exercise of choice. However, as individuals increase their fitness, and as their compliance to the exercise improves, different exercises may be introduced to strengthen weak muscles. For example, if the individual walks at work, their lower limbs may receive enough exercise and a physician may recommend exercises aimed at strengthening the rectus abdominus and diaphragm muscles to improve pulmonary capacity. Improving exercise capacity through walking and strengthening the rectus abdominus reduces fatigue and improves recovery time after exercise. Patients suffering from neuropathic pain and who have problems with their lower extremities may prefer swimming, cycling at home or exercises performed while sitting (Figure 1).

Figure 1. Twist sit-up can easily be performed by anyone.

In healthy individuals, an approximately 25% increase in exercise capacity is possible by the end of three months of training. To ensure improvements in capacity, the exercise program must include the principle of progressive overload. Intensity and duration of the exercise should be altered and other muscle groups may be included in the program at the appropriate time to ensure progression. Patients should be advised how and when to change their programs. The introduction of more intense, longer duration or new exercises will ensure continued adaptations and will improve program compliance.

7. Loading, progression and frequency of exercise

The exercise program must take into account personal preferences in terms of the mode of exercise, the venue and the capacity of the individual.

7.1. Phases of an exercise program

The first 5-10 minutes of an exercise session is the warm-up phase that prepares individuals for the main conditioning phase of the session. The second conditioning phase includes 20-40 minutes of continuous exercise that is performed at a specific intensity. The final third phase is the cool down period that lasts for 5-10 minutes (Table 3). It is crucial that an individual performs the warm-up and cool-down phases to ensure adequate preparation and recovery from exercise, respectively. The cool-down ensures adequate recovery of metabolic, cardiovascular, and neuroendocrine responses to within a normal range. If the individual cannot perform the exercise continuously it can be broken-up into intervals of exercise separated by rest periods or a reduced intensity.

1.	**Warm-up**: 5-10 minutes
2.	**Conditioning:** 20-40 minutes
3.	**Cool-down:** 5-10 minutes

Table 3. Three phases of an average exercise

7.2. Intensity, duration and frequency of exercise

Exercise plays an important role in health promotion and the maintenance of health. The intensity of exercise is regulated according to age, environmental conditions, physical capacity, the general health of the patient, as well as the aims of the program. The aims may include increasing endurance capacity, muscle strengthening, targeting of specific organ systems like the respiratory system, decreasing insulin resistance and weight-loss or weight maintenance.

For novice exercisers the program should promote health and ensure that the individuals remain motivated. The movements required during the initial phases of the program should be easy to perform and evoke a sensation of wellness and success. It is recommended that patients with diabetes perform life-long exercise if they have no contraindications and therefore they should find it easy to adapt to the exercise and the movements and goals should be achievable. Difficult exercise programs that are difficult to adapt should be avoided.

There are various opinions regarding the most appropriate exercise recommendations for healthy subjects. In general, aerobic exercise performed 3-5 times per week for no more than 20-40 minutes is advised. Up to 150 minutes of exercise (30 minutes/day) per week has been suggested to play a role in developing fitness and promoting health. As mentioned in the previous section, each exercise session that aims to improve cardiovascular adaptations, starts with light movements during the warm-up phase that aims to prepare the body for

exercise. This is then followed by 20-40 minutes of the main conditioning phase followed by a short period of cooling down. It is generally accepted that exercise time less than 20 minutes is not adequate for muscle (increased sarcolemma) or vascular adaptations (including coronary arteries) that include the stimulation of angiogenesis. The AHA recommends daily, moderate intensity exercise that lasts for 30 minutes or more. It takes time to achieve this recommendation, and therefore each exercise program should be individualized.

Generally, the method used to prescribe exercise intensity is to base each session on a specific percentage of an individual's age-predicted maximum heart rate. However, the use of this prediction may be dangerous for some people. For a healthy beginner, prediction of their maximum heart rate can be determined using 220 - age. In addition, a safe low to moderate intensity exercise target heart rate could be calculated using 160 - age. To improve endurance capacity the target heart rate could be calculated as 180 - age. It is difficult to measure heart rate during exercise if one is not using a portable heart rate monitor. A simple method of monitoring heart rate during exercise is to use the "talk test" [Quinn, 2011]. This refers to an intensity of exercise that allows an individual to talk (without dyspnea) to a partner exercising with them. The individual should slow down if they cannot speak comfortably to their partner. This simple method is recommended to regulate heart rate during exercise and to reduce the stress of worrying about heart rate in novice exercisers. Generally, if it is difficult to talk during exercise, this suggests that there is either a cardiovascular problem or in most cases hyperventilation due to lactic acid increase in circulation and metabolic acidosis related to anaerobic exercise. This "talk test" is especially important for individuals that have any kind of disease as well as elderly individuals in order to ensure that they perform exercise at a low to moderate intensity to minimize cardiac risks.

The metabolic equivalent (MET) unit is used to represent exercise intensity. One MET represents 3.5 mL O_2 uptake (oxygen consumption) per kg of muscle mass and is considered to be the metabolic rate of an individual at rest. Playing golf or walking at 4.5-6 km/hr is equal to 3-5 METs. A person weighting 70 kg, with a step length of 75 cm, walking 80 steps per minute (3.6 km/hr) will expend an additional 100 kcal/hr of energy [Porter et al., 2011]. Energy consumption will increase when walking speed increases. Playing tennis against a partner is equal to about 5-7 METs. Heavy occupational activity or walking/running at 9-10 km/hr is the equivalent of 9 METs. Moderate intensity exercise is considered to be 3-6 METs with the equivalent heart rate being 50-60% of maximal heart rate. High intensity or vigorous exercise is considered to be greater than 6 METs with the equivalent heart rate being ≥70% of maximum.

To ensure that the recommended caloric equivalents for healthy individuals are achieved, daily 20 minutes efforts (for 150 kcal energy consumption) excluding warming or 60 minutes efforts (for 300 kcal energy consumption) including warm-up are recommended. Personal health conditions, training experience, physiological and metabolic capacity, age, level of fatigue experienced, aims of the program should all be taken into account when planning the exercise program. With time, alterations will be made in the program to ensure

appropriate adaptations. It is important that education is provided to individuals regarding the planning and application of exercise.

A primary benefit of exercise training is the reduction of insulin resistance. A break from exercise that is longer than two days is not recommended in these patients because the exercise-induced insulin sensitization lasts for no longer than 72 hours after an exercise bout. If exercise is stopped for longer than 1-2 weeks then a new exercise program should be developed that takes into account that a level of detraining may have occurred. Therefore, the first week of exercise should be of a light to moderate intensity and shorter in duration to ensure that the individual does not start exercising too hard.

7.3. Exercise progression

Intensity, duration, and frequency of an exercise are increased slowly over a number of months to ensure that individuals continue to benefit from the program. The planning of the exercise progression should have the aim of ensuring that the individual does not experience excessive fatigue but experiences an increase in aerobic exercise capacity.

8. Exercise associated physiological and environmental conditions

8.1. Diabetes mellitus and food supplementation

Conditions differ for patients with type 1 and type 2 DM as well as for insulin using type 2 DM patients. Insulin dose adjustments are required when individuals with DM exercise to ensure that their plasma glucose levels are regulated. For example, a plasma glucose level of 200 mg/dL may decrease by 40-60 mg/dL after an hour of walking. This effect of exercise places patients with DM in a vulnerable situation if their glucose levels are not regulated suitably. A decrease in plasma glucose triggers counter mechanisms to increase plasma glucose and therefore exercise can only drop plasma glucose if there is hyperglycemia. However, individuals who have a tendency towards developing hypoglycemia are advised to perform exercise after eating appropriate food so that they can perform exercise without the risk of developing hypoglycemia.

8.2. Water supplementation and exercise

As water loss may cause fatigue and a decreased motivation to exercise, hydration practices before and during exercise must be taught. During exercise individuals should not drink more than one glass of water. Drinking a large amount of water may cause a full stomach. This in turn causes a redistribution of blood flow to the stomach that induces cardiac burden and a sensation of fatigue. It is recommended that appropriate amounts of water and food are consumed 30 minutes before exercise. If the individual gets thirsty during exercise, small amounts (100-200 mL/15 minutes) of water can be drunk at intervals. This will also help prevent an excessive rise in core temperature during the exercise. The amount of water lost in sweat is difficult to estimate during exercise due to the associations between climate, clothing and individual characteristics. However, individuals are advised to check their

weight-loss as a measure of fluid-loss and restore the lost water by drinking after exercise. A marathon runner may experience core temperatures of 38.5°C, similar to that of a fever, and may lose one liter of water per hour through sweating [Cheuvront, 2001]. After competitive exercise, it takes 2-4 days to replace lost water. One reason for this delay is the time it takes to distribute water to the intracellular and extracellular compartments. For these reasons, the amount of water lost during exercise should be monitored and precautions should be taken to maintain a healthy hydration status during exercise. Weighing individuals before and after exercise may help determine whether fatigue is related to water loss or because of anaerobic metabolism due to the exercise being too strenuous. Sweating also results in a loss of salts (NaCl) leading to a sensation of fatigue and discomfort. During summer and in hot climates excessive sweating should be avoided and unsuitable clothing that prevents heat loss should be avoided. Exercising individuals should replace the salt that is lost. Another problem is that the recommendation for restriction of salt intake is sometimes misunderstood and patients unfortunately stop salt intake. Salt intake must be in equilibrium and if salt intake is largely changed, it takes two months for the kidneys to adapt via tubular re-absorption. Salt depletion may result in fatigue and an increased consumption of sodium rich products like cola, salty biscuits, and adding extra salt to meals.

8.3. Environmental conditions

Hot, cold, windy or rainy conditions result in an extra circulatory burden and are not suitable for walking and sports performed outdoors. Exercise performed in the morning is more beneficial. Heavy exercise performed late in the evening increases metabolism and possibly disturbs sleeping patterns. Walking on level ground is preferred. Patients with DM should also avoid sudden increases in running speed to avoid sudden stress being placed on the cardiovascular system. Therefore, football is not a recommended sport for patients with DM. However, there are well-known insulin using professional football players with DM. Activities such as walking, swimming and tennis requiring whole body movements are preferable. The exercise area must also be clean, private and comfortable. Group sports may add to the enjoyment and improve group dynamics as well as have beneficial psychological effects.

8.4. Clothing

Clothing must be light, allowing the skin to breathe and to help sweat transfer away from the body and preferably be made from cotton. Socks made from cotton may keep the sweat inside the shoe and therefore are not appropriate. Thin wool socks transfer sweat and keep the foot dry thereby preventing injuries. Shoes that allow the foot to breathe and have a hard base, preventing unnecessary horizontal flexion but allowing slight vertical compression at the heel are recommended. Patients with neuropathy as well as the elderly should wear boots that support the ankles. This is because these individuals are more prone to early fatigue and they have difficulty in maintaining appropriate foot control. Using slightly compressible red soil tracks diminishes joint injury risk. However, it is not always possible to use such tracks, where it is advised to wear suitable shoes that have compressible heels. Persons with diabetes should not exercise wearing clothing such as nylon wind jackets because these prevent the skin from

"breathing" and may cause excessive sweating during the exercise. Exercising in hot environments places an extra stress on the body, and it is recommended that when exercising on hot sunny days that sunglasses and a hat are worn.

9. What kind of exercise to prescribe?

9.1. Aerobic exercise

Aerobic exercise promotes health and wellbeing. Aerobic exercise conditions the aerobic energy system to ensure that enough energy can be produced for movement by oxidative metabolism. During aerobic exercise, glucose, amino acid and fatty acid oxidation take place within the mitochondria. Fatty acid is transported into mitochondria via carnitine and degradation to acetyl-CoA occurs via beta oxidation. Glycolysis converts glucose into pyruvate and with the presence of oxygen in cells pyruvate is oxidized to acetyl-CoA. Fatty acids and glucose converted into acetyl-CoA that enters the citric acid cycle and oxidized to CO_2. Amino acid degradation also results in the formation of acetyl-CoA that also enters in the citric acid cycle. The chemical energy that is produced during these reactions is used for production of adenosine triphosphate (ATP). However, under anaerobic conditions (during high intensity exercise), glucose is converted into pyruvate in the cytoplasm, in the absence of oxidative metabolism. ATP synthesis in mitochondria is not available in the absence of oxygen and pyruvate does not enter the mitochondria. The result is that there is an increase in Nicotinamide adenine dinucleotide (NADH) in the cytoplasm, with the accumulated pyruvate in the cytoplasm being converted to lactic acid. Under anaerobic conditions the energy system works without oxygen and there is an increase in lactic acid that causes metabolic acidosis, fatigue, tachypnea and possibly sensation of dyspnea.

Studies on cardiopulmonary exercise test have shown that anaerobic metabolism increases, together with an accumulation of blood lactate, at an oxygen consumption of approximately 40-60% of maximal aerobic capacity (VO_{2max}) or a heart rate of 50-70% of maximal heart rate [Quinn, 2011]. To compensate for the increase in lactate and consequently increased CO_2 resulting in metabolic acidosis, hyperventilation occurs to release the excess CO_2. Hyperventilation and dyspnea can be used in a practical setting to guide exercise intensity. When dyspnea occurs, this may suggest that there is an increase in anaerobic metabolism and individuals should reduce their exercise intensity. The intensity of exercise that anaerobic metabolism occurs can be determined through an exercise test with gas analysis.

Overtraining, including exercising frequently at high intensities should be avoided by individuals who are not training for competition as well as individuals seeking health, fitness or weight-loss. Examples of aerobic exercise include walking and cycling. These exercises can be performed comfortably for long durations to improve fitness. Aerobic exercise enhances heart health and prevents the development of osteoporosis. When an individual experiences hyperventilation and a loss of concentration during exercise this may suggests an increase in anaerobic metabolism. High intensity or vigorous exercise causes an increase in the production of energy from anaerobic metabolism because energy production from the aerobic energy system is insufficient. The anaerobic energy system is most active

during high intensity, short duration exercise. For comfortable and healthy exercise, individuals should avoid intensive exercise that activates the anaerobic energy system. Sprinting, weightlifting and heavy physical activities all require anaerobic metabolism.

9.2. Flexibility exercise

Keeping joints flexible and improving flexibility are important for the rehabilitation of bed-ridden patients as well as the elderly. Warm-up and flexibility exercises help decrease the risk of injury during exercise. Following a suitable warm-up, soft and slow movements have a beneficial effect on muscle length and result in an improvement in joint range-of-motion. This in turn may correct body posture.

Flexion movements are recommended only when the body has undergone a warm-up condition. The warm-up will reduce muscle viscosity and increase flexibility and therefore reduce the risk of injury from flexion movements. This is the reason why experienced sportsmen continue to move and try to keep warm when a game is interrupted for a short period at any stage.

9.3. Resistance exercise for strength

Isometric contractions: These are contractions where force is generated in the muscle but there is no lengthening or shortening of the muscle. In addition, the object that the force is being applied to does not move. This type of contraction enables a better muscle contraction compared with weightlifting. Pushing the head against the stable hands is an isometric contraction and strengthens the neck muscles. These contractions are recommended in cases where joints movements are not indicated. Advantages include a low risk for injury as well as no equipment required (Figure 2).

Isotonic contractions: These are the typical weight-lifting movement where the mass of the object being lifted remains constant. This contraction is produced by lengthening and shortening of muscles (Figure3).

Isokinetic contractions: Measured using an isokinetic dynamometer. The speed of the contraction is regulated and kept constant however there is accommodating resistance (Figure 4). Isotonic and isokinetic exercises are preferred for elderly people. Isometric exercises increase blood pressure and cardiac burden.

During resistance exercise, the anaerobic energy system is dominant and there is an increase in both muscle mass and strength. Muscle and liver glycogen stores are also increased. If the exercise includes resistance or strength training, then the session should include 1-3 sets of 10-20 repetitions, with 20- 60 second rests between sets without allowing the individual to "cool-down". The rest periods between the sets should be adequate to ensure recovery (gaining power again) prior to the start of the next set. By the end of the exercise session the individual should feel a slight tiredness and must be satisfied with the exercise. Excessive tiredness should be avoided to ensure adherence to the exercise program. Well-known contraindications for exercise are listed in Table 4.

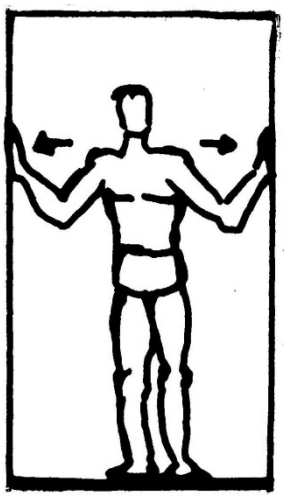

Figure 2. Isometric exercise (wall press)

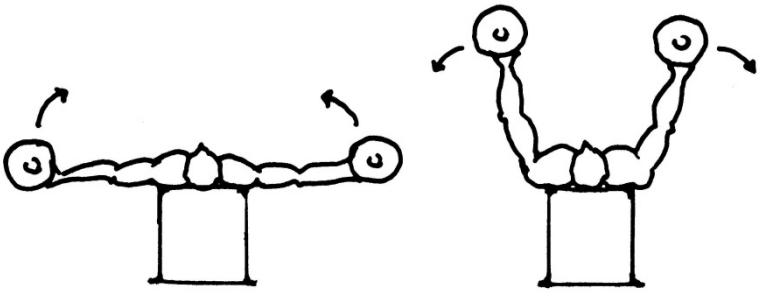

Figure 3. Isotonic exercise (pectoral strengthening)

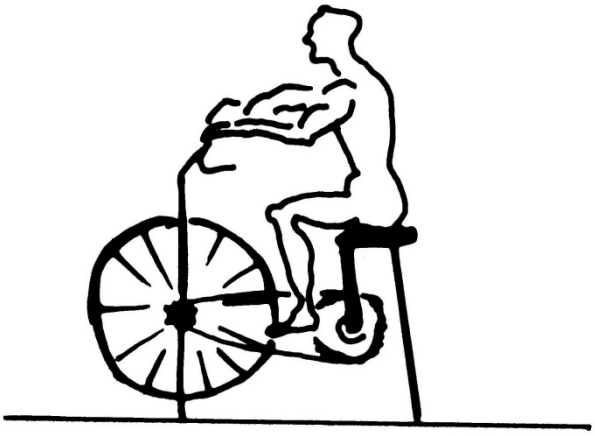

Figure 4. Isokinetic exercise (stationary bicycle)

For beginners a strength training program that includes of 1-3 sets of 8-12 repetitions of all the major muscle groups is recommended. The program may then be adjusted according to how the individual adapts. To prevent early fatigue it is important that the muscle group being exercised is considered. For example, to prevent fatigue in one muscle group, the exercise prescription recommended is 3 sets of 3 types of exercise, rather than 9 sets of one type of exercise.

1.	Excessive tiredness
2.	Hunger
3.	Cold sweating
4.	Tachycardia
5.	Dizziness
6.	Nausea and vomiting
7.	Respiration difficulty
8.	Chest pain or heaviness on the chest
9.	Impaired consciousness
10.	Excessive sweating and feeling of excessive mouth dryness.
11.	Pain at any location or sensation of cramping
12.	Balance impairment
13.	Blurred vision
14.	Low back pain or bleeding during pregnancy
15.	Fatigue
16.	Hypoglycemia
17.	Dehydration
18.	Uncontrolled hypertension
19.	Arrhythmia with syncope
20.	Unhealed injuries

Table 4. Contraindications for exercise

10. Diabetes and exercise

Exercise is recommended for all patients with DM if there is no contraindication however, it is important that they are educated regarding the impact of the exercise on their blood glucose levels. An exercise program consisting of at least 30 minutes of exercise 5 days per week (150 minutes/week) is recommended. As mentioned previously, each session would start with a 5-10 minute warm-up, followed by a conditioning period of 20-40 minutes of aerobic exercise, and then ending with 5-10 minutes of cool-down. All patients should be encouraged to be more physically active during the day. Walking is advised, rather than driving, for individual who live close to work. In addition, spending more time in the garden should be recommended. Sudden effort loading movements like climbing may activate anaerobic metabolism and ischemia and should be avoided.

Depending on the type of diabetes as well as the exercise session planned, consideration must be given to appropriate caloric intake before exercise. At the beginning of an exercise

session, energy is obtained from glycogen stores. A normal liver stores about 200 grams of glycogen. During prolonged exercise, glucose and fatty acids produced by the liver are used. However, exercise that lasts for 2-3 hours results in a reduction in glycogen stores and hypoglycemia may occur. If the depletion is treated by consuming glucose containing food like honey or jam then hyperinsulinemia may be experienced within 30 minutes resulting in a second hypoglycemic response. Walking at an average speed of 80 feet/min will only result in 100 kcal being expended per hour, while vigorous exercise results in an energy expenditure of 700 kcal in an hour. During comfortable walking, consumption of 20-40 grams of carbohydrate can maintain blood glucose levels. Prolonged exercises may cause an inhibition of insulin secretion and may stimulate counter regulatory hormones. Glucose transport into muscle cells is facilitated by muscle contraction. Hypoglycemia may occur at any time during exercise. After vigorous exercise, while the muscle and liver are replacing their glycogen and energy stores, hypoglycemia may occur in the periphery up to 24 hours after the exercise. Therefore, appropriate caloric intake should be maintained after vigorous exercise and insulin dose adjustments may be required.

10.1. Exercise for patients with type 2 diabetes mellitus

Exercise is recommended for patients with diabetes to decrease hyperglycemia. The increased prevalence of diabetes has been linked to sedentary behavior. Resistance exercise has been shown to be moderately beneficial as it delays mortality and reduce the risk of becoming a diabetic in populations where diabetes may be common. In addition, resistance exercise has been associated with reduced cardiovascular complications and mortality. Research demonstrated that the HbA1c values of elderly individuals (mean age 66 years) were decreased by 1-2 % after performing resistance exercise. Type 2 diabetes patients have hepatic and peripheral insulin resistance. Therefore, they can have hyperinsulinemia when they are hungry. However, during exercise, glucose uptake exceeds its production. Because exercise regulates plasma glucose there can be a decrease in insulin. The American Diabetes Association (ADA) recommends that if plasma glucose regulation is obtained through the intake of oral antidiabetic drugs then extra caloric intake is not required.

Patients with diabetes who plan to exercise should know how to check their plasma glucose levels before and after the exercise. They should also learn about the possible blood glucose changes that may occur during exercise and how to manage if anything goes wrong. Diuretic treatment modifications need to be provided to patients that sweat excessively during exercise. Patients using beta-blockers may experience a hidden hypoglycemia. Multi drug users must consult with their doctors regarding continued use of the drugs, as well as possible changes in their exercise regimen and caloric intake. Precautions must be adhered to at all times when they are exercising. For example, they may be required to carry small amounts of food with them. Patients with DM are advised to carry an identity card that includes an emergency contact telephone number as well as information that the person has diabetes. They could also wear a bracelet identifying that they have DM.

10.2. Exercise in insulin user patients with type 2 diabetes mellitus

Because exercise augments the insulin effect, the insulin doses that normally regulate plasma glucose may easily cause hypoglycemia. ADA recommends carbohydrate supplementation before exercise for individuals who use insulin or drugs that cause insulin secretion and in those individuals whose plasma glucose is less than 100 mg/dL (5.6 mmol/L). Insulin dose may be reduced in type 2 DM patients who exercise. In addition, 20-40 grams carbohydrate supplementation before exercise should also be considered. Over time the insulin requirements and response to insulin may change and therefore the patient must be monitored closely. Insulin users should determine blood glucose when the insulin effect is at its maximum level and when he/she should have to eat food. They should also be aware of the relationship between exercise and plasma glucose. Sulfonylurea- or insulin-using patients are more prone to experiencing hypoglycemia during exercise. However, hypoglycemia is not as frequent as in type 1 diabetes.

Exercise facilitates insulin absorption via increased blood flow to muscles and this may result in hypoglycemia. Insulin is preferably injected into sites away from the moving extremities/contracting muscle groups. Insulin user type 2 DM patients who exercise may use approximately 30-50% less insulin than usual although they should be aware of their glucose levels at all times. Before and after the exercise, plasma glucose measurements should be taken and it should be remembered that hypoglycemia may occur up to 24 hours after the exercise session.

10.3. Exercise in patients with type 1 diabetes mellitus

The insulin response and hypoglycemia risk differs from one patient to the other and therefore individual evaluation and education is mandatory. For patients with type 1 DM, plasma glucose measurements must be performed before and after the exercise. Insulin must be injected at the appropriate time to avoid hypoglycemia and 20-40 grams of carbohydrate is recommended before exercise. If the exercise will last more than an hour, and intake of 20-40 grams of carbohydrate per hour is recommended. Before exercise, food that is hard to digest should be avoided.

If the insulin dose is adjusted, patients with type 1 DM can perform most sports. The duration of exercise, loading level, injection placement, previous insulin dose and timing determines patients' insulin requirements when they exercise. Long acting insulin may result in a higher level of insulin than expected at the periphery. If insulin is injected into the actively contracting muscle this may cause a rapid absorption of the insulin and hypoglycemia may occur. Injuries and infections may increase insulin requirements. However, healing may decrease the amount of insulin requirements and this may result in hypoglycemia.

The hormone responses during exercise are inappropriate in type 1 DM. In these patients, even though insulin is deficient, exercise causes an activation of the counter insulin system leading to ketoacidosis. Acute and vigorous exercise stimulates the counter insulin responses, with catecholamines, growth hormone, glucagon and cortisol to increase blood

glucose and may cause hyperglycemia. However, hypoglycemia may occur 4-48 hours following the exercise.

When peripheral glucose use is restricted, lipid mobilization increases and ketogenesis is stimulated. In type 1 DM measuring ketones in the blood or urine is recommended if hyperglycemia exists. Hypoglycemia means excessive insulin or insufficient carbohydrate intake and ketonemia means insufficient insulin and carbohydrate. In type 1 DM exercise worsens the clinical situation if ketosis is present. Before exercise, if plasma glucose is under 100 mg/dL (5.6 mmol/L), it is advised that an individual consumes food containing carbohydrate such as fruit. Type 1 DM patients with plasma glucose ranging 100-250 mg/dL (5.6-14 mmol/L) do not need extra food prior to moderate exercise. Plasma glucose levels over 250 mg/dL (>14 mmol/L) and ketosis then require insulin and should receive extra attention [ADA, 2003]. Ketonuria should be checked before exercise. It may indicate that there is not enough insulin in the body. If there is a ketoacidosis risk then it is better to avoid exercising.

10.4. Exercise in pregnant women with diabetes mellitus

Exercise is important and is recommended for pregnant women with DM. Fitness and appropriate muscle tone reduces back pain related to muscle problems arising from the fetus weight. These exercises may also be beneficial during labor. The rectus abdominus, diaphragm and respiratory muscles are required to be strong to produce pressure during labor. In some countries there are group exercise programs to prepare pregnant women for labor. Before participating in an exercise program a gynecologic examination is mandatory. Exercise programs can be followed throughout pregnancy. Women who start exercising once they are pregnant and pregnant women with advanced age must be under the supervision of a physician.

Pregnant women should stop exercise when specific symptoms occur. These include lower back pain and vaginal bleeding. To prevent dehydration, drinking water before, during and after exercise is recommended.

Recommendations of The American College of Obstetricians and Gynecologists (ACOG) can be found at 'Gestational Diabetes (FAQ177)' and 'Exercise during treatment (FAQ 119)' (http://www.acog.org/For_Patients.aspx).

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